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STRUCTURAL ANALYSIS OF ROTOR DISC OF DISC BRAKE OF BAJA SAE 2013 CAR THROUGH FINITE ELEMENT ANALYSIS

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ABSTRACT

This paper deals with the structural analysis of rotor disc of disc brake of BAJA SAE 2013 CAR through finite element analysis approach using ANSYS software. A disc brake is a device by means of which artificial frictional resistance is applied to the rotating member, in order to stop the motion of a machine or a vehicle. The rotor discs are commonly manufactured of grey cast iron. The SAE also recommend grey cast iron for various applications. So it is being selected for investigation. The objective of structural analysis of rotor disc is to study & evaluate the performance under severe conditions & to suggest best combination of parameters of rotor disc like Flange Width, Wall Thickness & Material composition. In this present work, an attempt has been made to investigate the effect of stiffness & strength and to analyse the stability & rigidity of the rotor disc. The modelling of rotor disc is done in PRO/E wildfire 4.0 software. Further Structural analysis is done by using ANSYS 13.0 software. The Dimensions of an existing Maruti 800 car's disc rotor of disc brake are taken.

KEYWORDS: SAE BAJA 2013, Rotor Disc, Composite Materials, PRO/E Wildfire 4.0, FEA, ANSYS13.0

INTRODUCTION

The purpose of a brake system is to slow or halt the motion of a vehicle as desired by the driver within a minimum distance in an emergency. The working principle of brake operation is the conversion of energy. Energy is the ability to do work. The brake system converts the momentum of the vehicle into heat by slowing and stopping the vehicle's wheels. This is done by causing friction at the wheels.There are two basic types of friction that explain how brake systems work: kinetic, or moving, and static, or stationary. The resistance to motion of a vehicle or amount of friction produced is proportional to the pressure between the two objects, the type of materials in contact, & the smoothness of their rubbing surfaces. Friction converts the kinetic energy into heat. The greater the pressure applied to the objects, the more friction & heat produced, & the sooner the vehicle is brought to a stop.The following figure is representing the various types of friction acting on the vehicle during motion. Braking action creates kinetic friction in the brakes and static friction between the tire and road to slow the vehicle. When brakes are applied, the vehicle's weight is transferred to the front wheels and is unloaded on the rear wheels.

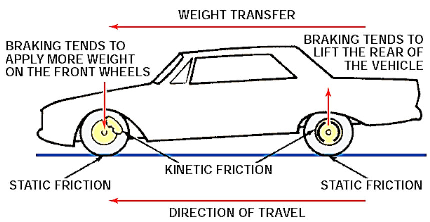


Figure 1: Friction Acting on a Vehicle

Figure 2: CAD Model of BAJA SAE 2013 Car

Figure 3: SAE BAJA 2013 Car at RJIT Gwalior Campus

Figure 4: Actual Disc Brake Assembly of BAJA SAE Car

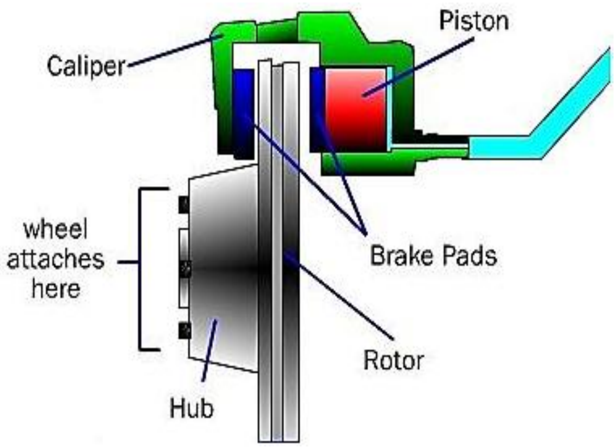


Figure 5: Working Principle of a Disc Brake

Disc brakes are used on the front of most modern road cars, and on all 4 wheels of most race cars. In disc brake the friction material are in the form of pads, which are fixed about the edge of a rotating wheel. With automotive disc brakes, this wheel is a separate unit mounted to the wheel, called the rotor. The rotor is typically made of cast iron.

The pads are attached to metal backings, which are actuated by pistons. The pistons are contained within a caliper assembly, which is a housing that wraps around the edge of the rotor. The caliper is mounted to the steering knuckle to stop it from rotating. The caliper contains the pistons and related seals, springs, bleeder screws, and boots as well as the cylinder(s) and fluid passages necessary to force the pads against the rotor. Disc brakes offer four major advantages over drum brakes. Disc brakes are more resistant to heat fade during high-speed brake stops or repeated stops. The design of the disc brake rotor exposes more surfaces to the air and thus dissipates heat more efficiently. They are also resistant to water fade because the rotation of the rotor tends to throw off moisture. The squeeze of the sharp edges of the pads clears the surface of water.

Rotor Disc of Disc Brake

The disc brake rotor has two main parts: the hub and the braking surface. The hub is where the wheel is mounted and contains the wheel bearings. The braking surface is the machined surface on both sides of the rotor. It is carefully machined to provide a friction surface for the brake pads. The entire rotor is usually made of cast iron, which provides an excellent friction surface.The size of the rotor braking surface is determined by the diameter of the rotor. Large cars, which require more braking energy, have large rotors. Smaller, lighter cars can use smaller rotors. Generally, manufacturers want to keep parts as small and light as possible while maintaining efficient braking ability. The rotor is protected from water and dirt due to road splash by a splash shield bolted to the steering knuckle. The outboard side is shielded by the vehicle’s wheel. The splash shield and wheel also are important in directing air over the rotor to aid cooling. The rotor discs are commonly manufactured of grey cast iron. The SAE also recommend grey iron for various applications.

Grey Cast Iron

The most common form of cast iron is grey cast iron. It is primarily composed of Iron 95%, Carbon 2 to 5%, Silicon 1 to 3%, but may also contain small percentage of Sulphur, Manganese & Phosphorus. In grey cast iron the carbon presents in the form of flakes which is distributed throughout the metal. More specific heat capacity & thermal conductivity are two main criteria for making grey cast iron rotor disc. Another mechanical property for grey cast irons includes Tensile strength, Shear Modulus of Rupture, young’s Modulus of Elasticity, Torsional Modulus of Elasticity, Compressive Strength, Brinell hardness & Endurance Limit. The stiffness and dampening properties of cast iron make it an excellent material for machine tool frames and parts. The material properties of grey cast iron are:

Density- 7100 kg/m3

Young modulus- 125 GPa

Poisson’s ratio- 0.25

Specific heat- 586 J/Kg.K

Thermal conductivity- 54 W/m.K

Aluminium Metal Matrix Composites

Metal matrix composites are mostly used in braking systems & engine parts of automobiles. Aluminium & magnesium is the most common matrix for the metal matrix composites. Aluminium Metal Matrix Composites are quite attractive due to their high fatigue strength, ultimate tensile strength, yield strength & low coefficient of thermal expansion. Aluminium Metal Matrix Composites have been utilized in automotive, aerospace, defence and thermal areas.The material properties of Aluminium metal matrix composites are:-

Density- 2820.6 kg/m3

Young modulus- 113.76 GPa

Poisson’s ratio- 0.35

Specific heat- 828.43 J/Kg.K

Thermal conductivity- 147.95 W/m.K

Figure 6: Maruti 800 Car’s Rotor Disc

METHODOLOGY

For structural analysis ofrotor disc of disc brake we have followed the step by step procedure.

Modeling of Rotor Disc

The modelling of rotor disc is done in PRO/ENGINEER 4.0 software.Pro/ENGINEER is parametric integrated 3D solid modelling software created by Parametric Technology Corporation, USA.Itwas the first parametric, feature-based, bi directional associative nature solid modelling software.For modelling the Dimensions of an existing Maruti 800 car’s disc rotor of disc brake are taken. But some assumptions are taken in modelling of rotor disc. In analysis we always ignore the things that have no or little impact on analysis. Some assumptions are such as rotor disc material is isotropic, there is no stress in rotor disc before the application of brake, rotor disc is of Solid type not ventilated, and brakes are applied on the all 4 wheels.

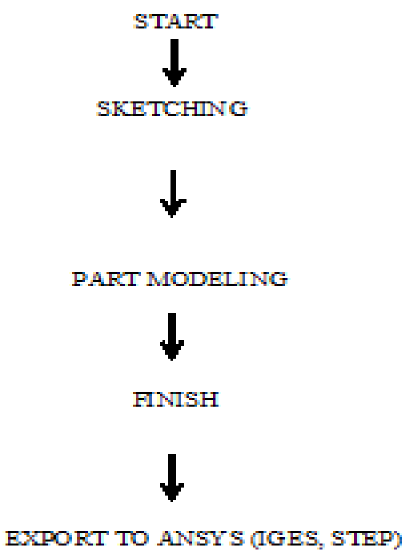


Figure 7: Rotor Disc Flow Chart

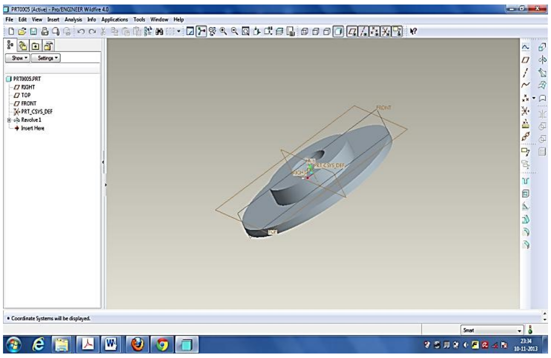


Figure 8: CAD Model of Rotor Disc in PRO/E 4.0

Finite Element Analysis (FEA)

Generally there are three methods to solve any engineering problems such as analytical method, Numerical method, & Experimental method in which numerical method is most commonly used. Because it is the mathematical representation of physical problems & it gives the approximate solution & also applicable even if physical prototype not available. Numerical methods like Finite element analysis are based on discretization of integral form of equation. Basic theme of all numerical method is to make calculations at only limited numbers of points & then interpolate the results for entire domain.It is now used to solve problems in the following areas- structural strength design, thermal analysis, vibration, & crash simulations etc.

FEA Software- ANSYS

ANSYS is general purpose FEA software developed, supported & marketed by ANSYS Inc. ANSYS are used by several companies to produce a wide range of products, including aircrafts & automobile engines. ANSYS involves three stages of activity: preprocessing, solution & postprocessing. A complete FEA analysis is a logical interaction of the three stages.

Preprocessing

It involves the preparation of finite element data such as nodal coordinates, element connectivity, boundary conditions, & loading & material information.

Solution

During the solution phase, FEA software automatically generates matrices that describe the behaviour of each element, assemble them & computes the unknown values of primary field variables such as displacement, temperature etc. additional derived variables such as reaction forces, stresses heat flow, can be computed by back substitution of the primary field variables.

Postprocessing

The postprocessing stage deals with the presentation of the results. Typically, the deformed configuration, mode shapes, temperature & stress distribution are computed & displayed at this stage. While solution data can be manipulated many ways in postprocessing, the important objective is to apply sound engineering judgement in determining whether the solution results are physically reasonable.

Structural Analysis in ANSYS

Structural analysis is the commonly used application of the FEA. We can perform the seven types of structural

analysis in ANSYS such as Static Analysis, Modal Analysis, Buckling Analysis, Spectrum Analysis, Harmonic Analysis, Transient dynamic Analysis, Explicit dynamic analysis.A static analysis is performed over a structure when the loads & boundary conditions remain stationary & do not change over time it is assumed that the load or field conditions are applied gradually, not suddenly. The system under analysis can be linear or nonlinear. Inertia and damping effects are ignored in structural analysis.Static analysis is used to determine displacements, stresses & so on.In structural analysis following matrices are solved **[K][X]= [F],**Where **K** is stiffness matrix, **X** is displacement matrix, &**F** is the force matrix. The above equation is called the force balance equation for the linear system. Nonlinear systems include large deformation, plasticity, and creep and so on.

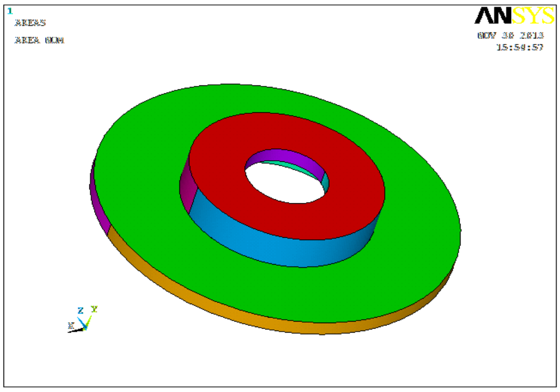


Figure 9: Solid Model of Rotor Disc in ANSYS after Removing Holes & Fillets

START ANSYS 13.0

↓

MODEL IMPORT FROM PRO/E WILDFIRE 4.0

↓

MODEL GEOMETRY CHECKING

↓

SELECT PROBLEM DOMAIN (STRUCTURAL)

↓

ELEMENT TYPE SELECTION

↓

MATERIAL PROPERTIES SELECTION (E, PRXY)

↓

MESHING (DISCRETIZATION-NODES & ELEMENTS)

↓

APPLY BOUNDARY CONDITIONS

↓

APPLY LOADS

↓

SOLVE

↓

CHECK DEFORMATION

↓

CHECK STRESS VALUE

↓

GENERATE GRAPHS & REPORT

Figure 10: FEA Flow Chart (Structural Analysis in ANSYS)

RESULTS

The objective of structural analysis of rotor disc is to study & evaluate the performance under severe conditions & to suggest best combination of parameters of rotor disc like Flange Width, Wall Thickness &Material composition. In this Structural analysis we Obtained Von misses stress& Hoop Stress. Because it is a very important parameter for design engineers.Using this information we can say our design will fail, if maximum value of Von Misses stress induced in the material is more than strength of the material.According to the given specification of rotor disc of disc brake the element type chosen for structural analysis is solid 20node 95.

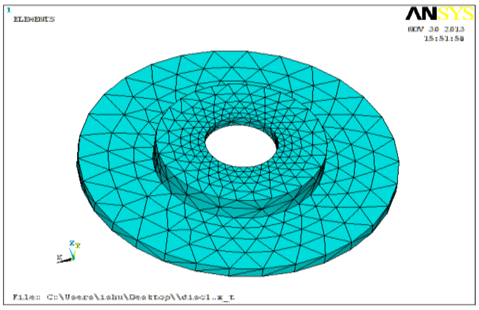
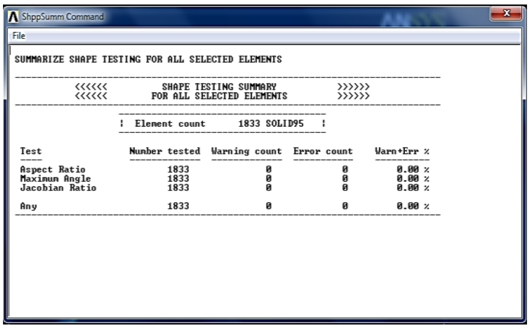


Figure 11: Meshed Model of Rotor Disc in ANSYS


ShppSumm Command

File

SUMMARIZE SHAPE TESTING FOR ALL SELECTED ELEMENTS

<<<<<< SHAPE TESTING SUMMARY >>>>>>
<<<<<< FOR ALL SELECTED ELEMENTS >>>>>>

| Element count 1833 SOLID95 |

Test	Number tested	Warning count	Error count	Warn+Err %
Aspect Ratio	1833	0	0	0.00 %
Maximum Angle	1833	0	0	0.00 %
Jacobian Ratio	1833	0	0	0.00 %
Any	1833	0	0	0.00 %

Figure 12: Shape Testing Report for SOLID95 Element in ANSYS

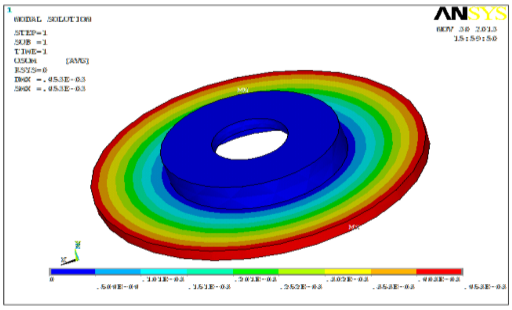


Figure 13: Displacement Vector Sum in Rotor Disc

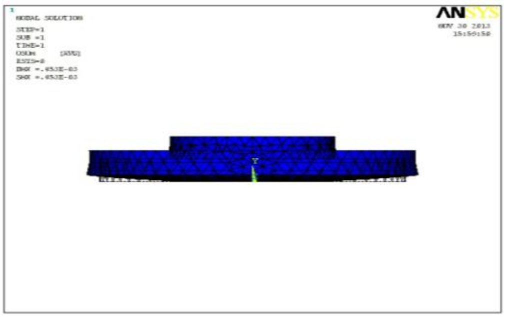


Figure 14: Average Displacement in Rotor Disc

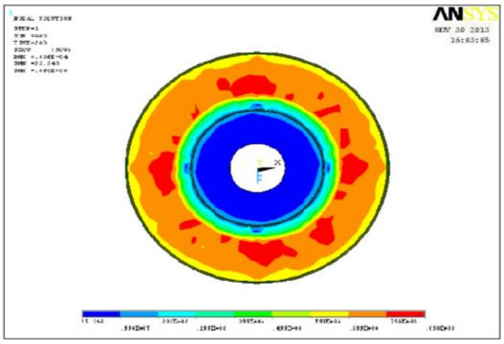


Figure 15: Von Misses Stress Distribution in Rotor Disc

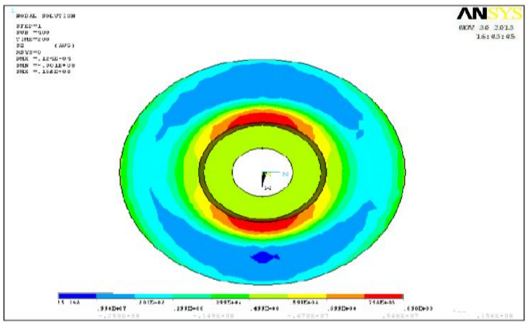


Figure 16: Hoop Stress Distribution in Rotor Disc

CONCLUSIONS

Rotor Disc Material- Grey Cast Iron

Max. Displacement - 0.0753 mm

Von Misses Stress - 87.8 MPa (Max.)

Hoop Stress- 55.2 MPa. (Max.)

Our college team participated first time in SAE INDIA BAJA 2013 event & won prize. A comparative study of various components of vehicle as per SAE INDIA BAJA 2013 specification was taken as our approach. In this paper structural analysis of rotor disc of disc brake has been performed. The objective of structural analysis of rotor disc is to study & evaluate the performance under severe conditions & to suggest best combination of parameters of rotor disc like Flange Width, Wall Thickness & Material composition. In this present work, an attempt has been made to analyse the stability & rigidity of the rotor disc. From the above analysis we can say that the obtained stresses are less than the design stresses. So Maruti 800 Car's rotor disc is suitable for present application.

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